Your review of Chemistry 20 for Chemistry 30 will be more successful if you study the highlighted Summaries, Sample Problems, and Communication Examples in each chapter. By answering the following questions you will find out where you need to check your understanding before starting Chemistry 30.

Unit 1 Chemical Bonding
(Chapter 3)

1. Distinguish between the two important types of scientific knowledge.
2. Identify the characteristics of acceptable scientific theories.
3. Explain the octet rule and how it relates to chemical reactivity.
4. Copy and complete the following table.

Table 1 Theoretical Descriptions of Selected Elements

Element name	Lewis symbol	Group number	Number of valence electrons	Number of lone pairs	Number of bonding electrons
calcium					
aluminium					
arsenic					
oxygen					
bromine					
neon					

5. (a) State the types of elements expected to react to form compounds containing covalent bonds.
   (b) State the types of elements expected to react to form compounds containing ionic bonds.
   (c) Explain your answers to (a) and (b) using the concept of electronegativity.
   (d) Why is it difficult to predict the type of bonding in some compounds using only electronegativities?
6. The two major types of compounds are ionic and molecular.
   (a) Compare the naming of these compounds.
   (b) Given the name of an example of each compound, outline how the chemical formula is obtained. Use specific examples in your answer.
7. Theories are created to explain observations. For each of the following properties of ionic compounds, write a brief theoretical explanation.
   (a) Ionic compounds are hard solids with high melting and boiling points.
   (b) Ionic compounds are electrical conductors in molten and aqueous states.
8. Using Lewis symbols and formulas, write the formation equation for each of the following compounds.
   (a) potassium bromide
   (b) sodium oxide
   (c) calcium fluoride
9. Why are chemical formulas for ionic compounds always based the simplest whole number ratio of ions? Is the simplest whole number ratio also used for molecular formulas? Why or why not?
10. Compare ionic and covalent bonds, including how they are formed, according to theory and the nature of the bond.
11. For each of the following molecular formulas, draw the Lewis, structural, and stereochemical formulas, and state the shape around the central atom.
    (a) OCl_2 (d) HCN
    (b) SiH_4 (e) CH_2O
    (c) NCl_3
12. Classify each of the molecules represented in the previous question as polar or nonpolar. Justify your answer using the molecular shape and bond dipoles (charge distributions).
13. Methylisocyanate is a toxic pesticide that is manufactured using the following chemical reaction.
    $CS_2 + CH_3NH_2 \rightarrow CH_3NCS + H_2S$
    Rewrite this chemical equation using structural formulas for all reactants and products.
14. Define the three types of intermolecular forces. For each type of force, state how you would know if this type of force is likely present among molecules of a substance.
15. Each of the following four substances is either a liquid at SATP or converted to a liquid by changing the conditions: C_3H_7F, $C_3H_5(OH)_3$, $C_3H_7NH_2$, C_3H_8
    (a) Construct a table to summarize the types of intermolecular forces believed to be present among molecules of each of these substances.
    (b) Predict the order of boiling points from lowest to highest. Justify your answer.

16. Why are boiling points often used as an indirect measure of the strength of intermolecular forces among molecules of a substance?
17. Explain each of the following observations in terms of the characteristics of molecules and intermolecular forces.
    (a) The boiling point of fluorine is significantly less than that of chlorine.
    (b) Drops of ethanol are attracted to an electrically charged strip.
    (c) Ice has a regular hexagonal structure.
18. A simple, but useful, distinction that is often made is to classify the water on Earth as either fresh water (as in most lakes and streams) or salt water (as in the oceans).
    (a) Contrast these two terms from a scientific perspective.
    (b) How is this distinction useful from a technological perspective?
19. Describe an example in which scientific research led to the development of a new technology.

Unit 2 Gases (Chapter 4)

1. List seven ways by which empirical knowledge is communicated.
2. List the three characteristics of acceptable scientific laws and generalizations.
3. Describe one natural phenomenon and one technological product that each depend on the properties of gases.
4. Complete the following statements.
    (a) At a constant temperature and chemical amount of gas, as the pressure increases, the volume _____.
    (b) At a constant pressure and chemical amount of gas, as the temperature decreases, the volume _____.
    (c) At a constant volume and temperature, if the chemical amount of gas inside a container is increased, the pressure _____.
5. Choose one of the statements in question 4 and write a general design for an experiment to test the statement. Include the identification of all important variables.
6. For each statement in question 4, sketch a graph of the relationship between the manipulated and responding variables.
7. Convert 95.8 kPa into units of millimetres of mercury and atmospheres.
8. A 1.5 L volume of gas is compressed at a constant temperature from 1.0 atm to 5.0 atm. Calculate the final volume.
9. A balloon can hold 800 mL of air before breaking. A balloon at 4.0 °C containing 750 mL of air is allowed to warm up. Assuming a constant pressure inside the balloon, determine the minimum Celsius temperature when the balloon breaks.
10. A sample of argon gas at 101 kPa and 22.0 °C occupies a volume of 150 mL. If the volume doubles at a temperature of 150 °C, determine the new pressure.
11. Using the kinetic molecular theory, explain Boyle's and Charles' laws.
12. Illustrate the law of combining volumes using a simple example. Describe the theory used to explain this law.
13. Many people use propane barbeques for outdoor cooking. Predict the volume of carbon dioxide produced when 15 L of propane completely burns at SATP.
14. Describe and compare the behaviour of real and ideal gases using the kinetic molecular theory.
15. Predict the volume that 25.0 g of oxygen gas would occupy at 22.0 °C and 98.1 kPa.
16. Compare the volume that 0.278 mol of hydrogen would occupy at STP and SATP.
17. An average bungalow requires about 400 kmol of methane per year for space heating.
    (a) Determine the volume of methane at SATP used in one year.
    (b) Predict the volume of methane used if the pressure is 98.5 kPa and the temperature is 12.7 °C.

Unit 3 Solutions, Acids and Bases (Chapters 5 & 6)

1. For each of the following perspectives write a brief statement describing the focus or concern of that point of view.
   - scientific
   - technological
   - economic
   - ecological
   - political
2. List three topics that are current STS issues.
3. Classify each of the following statements using one of the issue perspectives listed in question 1. All of the statements concern sulfur dioxide emissions.
   (a) An industry spokesman reported that emissions of sulfur dioxide were within the limits set by environmental legislation.
   (b) Laboratory research has provided evidence that sulfur dioxide from the combustion of fossil fuels is converted to sulfur trioxide in the presence of oxygen.
   (c) The cost of ending sulfur dioxide pollution of the atmosphere will be high. The longer we delay facing the problem, the greater will be the cost.
   (d) Sulfur oxides and their related dissolved acids are particularly damaging to soil microbes, water life forms, plants, building materials, and people.
   (e) One of the most promising scrubbers to remove sulfur dioxide gas from a smoke stack is the limestone–dolomite process.
4. Compare the goals of science and technology.
5. Describe a homogeneous mixture and provide several examples.
6. Define the two main parts of a solution. State an example using a chemical formula and identity the two parts in words.
7. In the exploration of outer space, scientists usually look for the presence of water as a strong indication of the existence of living things. Briefly explain this statement in terms of solutions and reactions.
8. List at least six examples of manufactured solutions found in the home and six examples of natural solutions found in the environment.
9. Distinguish between electrolytes and non-electrolytes, including examples of types of substances in each category.
10. Explain, in terms of breaking and forming bonds, why the dissolving of substances in water can be either exothermic or endothermic.
11. Compounds may be ionic or molecular and may also be acids, bases, or neutral compounds.
    (a) Design an experiment to classify the solute in each of a number of different solutions.
    (b) Outline the expected results.
12. Write dissociation or ionization equations for the following pure substances dissolving in water.
    (a) lithium phosphate solid
    (b) hydrogen chloride gas
    (c) aluminium sulfate solid
13. For each of the following pure substances, write the formulas for the entities present when each substance is placed in water.
    (a) $Sr(OH)_2(s)$ (d) $CH_3COOH(l)$
    (b) $HNO_3(l)$ (e) $AgCl(s)$
    (c) $C_3H_8(g)$ (f) $CH_3OH(l)$
14. List the three advantages of solutions for technological applications.
15. Suppose you are given four unlabelled beakers, each containing a colourless aqueous solution of one solute. The possible solutions are NaCl(aq), HCl(aq), $BaCl_2(aq)$, and $CH_3Cl(aq)$. Write a series of diagnostic tests to distinguish each solution from the others.
16. Compare the ways in which solution concentrations are expressed in chemistry labs, consumer products, and environmental studies.
17. A household cleaner contains 12.5 g of sodium hypochlorite in 500 mL of solution. Determine the percentage mass by volume concentration of this solution.
18. A drain cleaner contains 2.75 mol/L sodium hydroxide. Calculate the volume of solution that contains 0.375 mol of sodium hydroxide.
19. A windshield washer solution was prepared by dissolving 100 g of methanol in water to form 2.00 L of solution. Calculate the amount concentration of the solution.

20. A 0.251 mol/L calcium chloride solution is required for an experiment.
    (a) Calculate the mass of calcium chloride that needs to be measured.
    (b) Write a specific procedure for an untrained laboratory technician to prepare this solution.
21. (a) Predict the volume of concentrated, 14.6 mol/L phosphoric acid required to prepare 250 mL of a 0.375 mol/L solution.
    (b) Write a specific procedure to prepare this solution.
22. Calculate the amount concentration of each ion in a 2.1 mol/L solution of iron(III) chloride?
23. How does the solubility of solids and gases change as the temperature increases?
24. Excess copper(II) sulfate is added to water in a closed system until no more solute dissolves at a constant temperature.
    (a) Describe some empirical properties of this mixture.
    (b) Provide a brief theoretical explanation of these properties.
25. Write the acid formula for each of the following substances.
    (a) aqueous hydrogen bromide
    (b) aqueous hydrogen sulfite
    (c) hydrofluoric acid
    (d) sulfuric acid
26. Copy and complete the following table.

Table 2 Hydroxide Concentrations and pHs

$[H_3O^+(aq)]$ (mol/L)	pH	Acidic/basic/neutral
1.0×10^{-7}		
	8	
	3.7	
6.23×10^{-9}		

27. The pH of pure water is 7, of carbonated water about 5, and of a cola drink about 3. How many times more acidic is a cola drink than carbonated water and pure water?
28. Use the modified Arrhenius theory to write chemical equations explaining the following evidence.
    (a) A vinegar solution is acidic.
    (b) A baking soda (sodium hydrogen carbonate) solution has a pH of 8.
    (c) Some muriatic (hydrochloric) acid is neutralized with a lye (sodium hydroxide) solution.
29. A simple window cleaning solution containing 0.25 mol/L ammonia has a pOH of 2.5.
    (a) Convert the pOH into an amount concentration of hydroxide ions.
    (b) Write a balanced chemical equation to explain this basic solution.
    (c) Is ammonia a strong or weak base? Justify your answer.
30. Write a design for an experiment to identify strong and weak acids. Include three different diagnostic tests and identify important controlled variables.
31. Polyprotic acids and bases occur naturally and are manufactured for a variety of purposes.
    (a) Distinguish between monoprotic and polyprotic acids and bases.
    (b) Using boric acid (aqueous hydrogen borate) as an example, write a series of chemical equations showing successive reactions with water.
32. Most scientists agree that the increasing emission of carbon dioxide into the atmosphere from the burning of fossil fuels is the prime cause of global warming. This problem might be even worse if it were not for the fact that approximately half of the carbon dioxide produced is absorbed by the world's oceans. However, recent research has shown that this is making the oceans more acidic—about 30% more acidic over the past two hundred years.
    (a) Use the modified Arrhenius theory to write a chemical equation explaining the increased acidity of the world's oceans.
    (b) Scientists are not certain what effect the increased acidity will have. If we assume there will be a problem in the oceans, describe some solutions to reduce the addition of carbon dioxide to the oceans.
33. Using pesticides as an example, summarize the intended and unintended consequences of this chemical technology.

Unit 4 Quantitative Relationships
(Chapters 7 & 8)

1. Compare the fields of chemistry and chemical technology.
2. Describe two examples of chemical technologies, used by consumers, that are based on the stoichiometry of chemical reactions.
3. Distinguish between qualitative and quantitative chemical analysis and provide an example of each type of analysis.
4. For each of the following mixtures, write a balanced net ionic equation and identify all spectator ions. All reactant solutions are assumed to be at least 0.10 mol/L in concentration.
   (a) sodium hydroxide and cobalt(II) chloride solutions
   (b) silver nitrate and calcium iodide solutions
   (c) silver nitrate solution and zinc metal
   (d) hydrochloric acid and solid calcium hydroxide
   (e) the precipitation of aluminium hydroxide in qualitative analysis
5. In your own words, describe the meaning of stoichiometry.
6. List the three types of stoichiometry and describe how each type is recognized.
7. In general, how do chemical industries use the principles of stoichiometry to maximize yields and minimize waste?
8. In the steel industry, carbon reacts with iron(III) oxide (from iron ore) to produce molten iron and carbon dioxide.
   (a) Write a complete balanced chemical equation for this reaction.
   (b) Translate this chemical equation into an English sentence including all chemical amounts and states of matter.
   (c) Using the coefficients, calculate the mass of each reactant and product in this balanced chemical equation.
   (d) How does the total mass of reactants compare with the total mass of products? What principle does this illustrate?
9. Predict the mass of lead(II) iodide precipitate that forms when 2.93 g of potassium iodide in solution reacts with excess lead(II) nitrate.
10. In a hard water analysis, a calcium chloride solution is reacted with excess aqueous sodium oxalate to produce 0.452 g of calcium oxalate precipitate. Determine the mass of calcium chloride present in the original solution.
11. Analysis for sulfate ions is usually done by first precipitating barium sulfate from a sample. The filter paper containing the barium sulfate precipitate is then ignited. Carbon from the burnt filter paper then reacts with the barium sulfate as shown in the balanced chemical equation below.
    $BaSO_4(s) + 2\ C(s) \rightarrow BaS(s) + 2\ CO_2(g)$
    (a) Predict the mass of carbon required to react with 1.50 g of barium sulfate precipitate.
    (b) List the assumptions you have made in this calculation.
12. In a test of the stoichiometric method, an excess of sodium hydroxide solution is reacted with a solution containing 1.50 g of aluminium sulfate.
    (a) Predict the mass of precipitate expected in this reaction.
    (b) If the actual yield in this experiment was 0.96 g of precipitate, calculate the percent yield.
    (c) Outline at least three possible reasons for the discrepancy between the theoretical (predicted) yield and the actual yield.
13. Powdered aluminium metal is one of the fuels used in the solid rocket boosters for the NASA Space Shuttle. What volume of oxygen at SATP is required to react completely with 100 kg of aluminium?
14. A portable hydrogen generator uses the reaction of solid calcium hydride and water to form calcium hydroxide and hydrogen. Determine the volume of hydrogen at 96.5 kPa and 22 °C that can be produced from a 50 g cartridge of $CaH_2(s)$.
15. A volumetric analysis shows that it takes 32.0 mL of 2.12 mol/L NaOH(aq) to completely react with 10.0 mL of sulfuric acid from a car battery. Calculate the amount concentration of sulfuric acid in the battery solution.

16. In a laboratory, silver metal can be recycled to produce silver nitrate by the following reaction.

$$3\ Ag(s) + 4\ HNO_3(aq) \rightarrow 3\ AgNO_3(aq) + NO(g) + 2\ H_2O(l)$$

Predict the volume of 15.4 mol/L nitric acid required to react with 1.68 kg of silver metal.

17. Distinguish between limiting and excess reagents.
18. Describe the purpose of using an excess reagent in a quantitative analysis?
19. Calcium carbonate is commonly used in simple antacid products to counteract acidity in the stomach. Suppose you add a 750 mg tablet of calcium carbonate to 200 mL of 0.10 mol/L hydrochloric acid (representing the stomach acid).
    (a) Which reactant is in excess and by how much? Give your answer in moles.
    (b) Predict the mass of calcium chloride formed in this reaction.
20. Complete the Materials and Analysis of the following lab report.

Problem

What is the amount concentration of an unknown sodium carbonate solution?

Design

Samples of sodium carbonate solution were titrated with a standardized hydrochloric acid solution using methyl orange as the indicator.

Evidence

Table 3 Titration of 25.0 mL Samples of $Na_2CO_3(aq)$ with 0.352 mol/L HCl(aq)

Trial	1	2	3	4
Final burette reading (mL)	16.5	31.8	47.0	16.4
Initial burette reading (mL)	0.6	16.5	31.8	1.2

22. Titration curves are useful in studying the progress of a reaction, such as an acid–base reaction.
    (a) Sketch a general curve for the titration of a strong base with a strong acid. Label the axes and provide a title for the graph. No numbers are required.
    (b) Place an "X" on the curve where the reaction is complete. At what pH should this occur?
    (c) Identify a suitable indicator for any strong base–strong acid titration and justify your answer.
    (d) Would your answers to (a), (b), and (c) change if a strong acid were titrated with a strong base? Note any differences.

You have been preparing for the Diploma Exam throughout your high school career. In your final year, as you work through the Chemistry 30 course, here are some tips that will help you perform as well as you possibly can in the Diploma Exam.

- **Involve Yourself in Class**: Attend class regularly and be active in your learning by asking questions and completing assignments. If you work steadily, there will be no need to try to learn everything just before the exam.
- **Keep Up-to-Date with Chemistry 30 Material:** Schedule a regular review time every week and use this time to organize your notes, review the material, and ask yourself questions about what you have learned. Use the Self Quizzes, Chapter Summaries, and other study aids.
- **Read and Understand the Scoring Criteria for Diploma Exams**: The full scoring criteria for the different types of questions are available in the Chemistry 30 Information Bulletin found online. Read these criteria carefully and make sure you understand what they mean.

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- **Practice Writing Old Exams**: Simulate the conditions of the exam to get used to sitting through an entire exam and the time constraints of writing the exam. You will also get used to the types of questions on the exam and, afterward, be able to compare your answers to the scoring criteria.
- **Read the Instructions**: Make sure you read the instructions, directions, and questions very carefully.
- **Become Familiar with the Types of Questions**: Read the information below and practice answering each type of question.

There are three types of questions on the Diploma Exam: multiple choice, numerical response, and written response.

Multiple Choice Questions

Multiple choice questions are a large part of the diploma exam. Most of the multiple choice questions on the diploma exam are context-dependent. The others are called "discrete."

Context-dependent multiple choice questions use information provided in addition to the actual question. Examples of this type of question include questions 10 and 11 in the Unit 2 Review.

Use this information to answer questions 9 to 11.

The empirical study of gases provided a number of laws that formed the basis for important developments in chemistry such as atomic theory and the mole concept.

Statements

1. The volume of a gas varies inversely with the pressure on the gas.
2. Volumes of reacting gases are always in simple, whole number ratios.
3. The volume of a gas varies directly with the absolute temperature of the gas.
4. The volume of a gas varies directly with the absolute temperature and inversely with the pressure.

10. Which statements require that the temperature be a controlled variable?
    A. 1, 2, 3, and 4
    B. 1, 3, and 4 only
    C. 1 and 2 only
    D. 3 and 4 only
11. Identify the statement that is best explained by Avogadro's theory.
    A. 1
    B. 2
    C. 3
    D. 4

Discrete multiple choice questions have no additional information or directions, such as questions 1 and 2 in the Chapter 7 Review.

1. A main goal of technology is to
   A. advance science
   B. identify problems
   C. explain natural processes
   D. solve practical problems
2. In the reaction of aqueous solutions of sodium sulfide and zinc nitrate in a chemical analysis, the spectator ions are
   A. sodium and nitrate ions
   B. sulfide and zinc ions
   C. sodium and zinc ions
   D. sulfide and nitrate ions

When answering multiple choice questions:

- Try to answer the question before looking at the choices.
- Eliminate any choices that are incorrect by crossing them out.
- Stay alert for key words: *most, least, not one of the following*, etc. Negative terms ("Which of the following is *not* a physical property of a gas?") will be italicized. Look out for these.
- Choose the correct answer on the question sheet and then fill in the corresponding circle on the answer sheet. It is important that you stay aware of time, so that you don't run out of time to transcribe your answers from the question sheet to the answer sheet.

Numerical Response Questions

Numerical response questions on the Diploma Exam are clearly indicated with the heading "NUMERICAL RESPONSE." Examples of these types of questions are clearly marked with the icon "NR" in this textbook. There are four types of numerical response questions on the Diploma Exam. They are

- calculation of numerical values,
- calculation of numerical values expressed in scientific notation,
- selecting numerical responses from diagrams or lists, and
- determining the sequence of listed events.

Specific instructions for recording the answer to each type of numerical response are given in the instructions of the Diploma Exam, as well as with each question. Read the instructions *carefully*.

- **Numerical calculations**: This category is fairly straightforward. You have to use the provided data to calculate an answer. The answer is a numerical response with a maximum of four digits (including the decimal point). The first digit of your answer goes in the left-hand box on the answer sheet. Depending on the number of digits in your answer, there may be unfilled boxes to the right. The decimal point, if there is one, occupies one of the boxes. If an answer has a value between 0 and 1, for example 0.25, make sure you record the '0' before the decimal point.
- Calculations requiring an answer in **scientific notation:** This category is similar to regular numerical calculations, except that the four digits of the response come from an answer in the form $\boldsymbol{a.b} \times 10^{\boldsymbol{cd}}$. When you have completed your calculation, just write the four digits represented by ***a***, ***b***, ***c***, and ***d*** in order.
- **Numerical responses from diagrams or lists**: This category involves selecting numbers (usually representing a term or item from several provided) and writing them in the correct order.
- **Sequence of numbered events or data**: These questions ask you to rearrange variables, events, or data into a specified order. Pay particular attention to the instructions, which might specify, for example, "in order of increasing melting temperature."

Written Response Questions

There are two written response questions on the Chemistry 30 Diploma Exam. One written response question is a closed-response question (which has only one correct response) and the other is an open-response question (which has more than one correct response).

Learn to determine which type of question is being asked. **Closed response questions** have specific questions that must be directly answered. These questions are presented as sections and subsections (question 1. a, b, c, etc.). **Open response questions**, or holistic questions, typically begin with an instruction followed by a series of bullets. You are expected to write your answer in full sentences. Each bullet must be addressed and your responses combined into the answer.

When answering written response questions

- Carefully read the information box and make sure you fully understand the material *and* all of the question parts before beginning to answer.
- Identify each key piece of information and make notes about the meaning and implications of that information. If it helps, mark key words and phrases. Identify which unit of Chemistry 30 is being addressed. This will help you focus your attention to the correct material.
- Identify any irrelevant information.

- Identify the **directing words** in the question. These are usually highlighted in bold in the question. The directing words have specific meanings and are indicators of what the graders expect for an answer. Examples of directing words include **illustrate**, **analyze**, **explain**, and **predict**. A complete list of directing words and their meanings can be found online. These words are also included and defined in the Glossary. In your preparation, refer to the list of meanings for directing words. Make sure that you know what is expected for each directing word.

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- Read the question carefully and ask yourself what you are being asked to do. Write the question out in your own words if there are any doubts. Remember, if you don't understand the question, you will probably not be able to answer it correctly!
- Summarize your answers on scrap paper before writing them on the test answer page.
- Once you have answered the question, review your answer and make sure you have addressed all parts of the question. This is especially important for the open response question.

Answering Closed Response Questions

Closed response questions are often based on a summary of current research or a scenario, and data may be given in graph or table format. There are several parts to the question, but the number of parts depends on the context of the question. An example of a closed response question follows. This one is taken from the Chapter 13 Review.

35. Vanadium is a very versatile element in terms of its reactivity. Vanadium metal reacts with fluorine to form VF_5, with chlorine to form VCl_4, with bromine to form VBr_3, with iodine to form VI_2, with oxygen to form V_2O_5, and with hydrochloric acid to form VCl_2.
    (a) Identify the oxidation states of vanadium in each of these compounds.
    (b) What interpretation can be made about the oxidizing power of the chemicals that react with vanadium metal?
    (c) Describe how the oxidation state of vanadium relates to the colours of the compounds formed.
    (d) Report on some technological applications of vanadium and its compounds.

Complete examples of closed-response questions are online.

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Each section of the question must be answered completely for full marks. The number of marks for the question is given in parentheses. Use this as a guide for how detailed your answer should be.

Answering Open Response Questions

Open response questions are often based on a situation or scenario. You are generally asked to write an essay-type response, guided by the directing word in the question. Following the initial question are several points. Your responses to these points should be integrated into your answer.

34. For the production of pulp from wood, a variety of methods are used, including mechanical and chemical processes. These have advantages and disadvantages that have been widely debated. Prepare an argument for or against the following statement: "The immediate economic value of using technology to produce a product far outweighs any possible future adverse effects."

    Your response should also include

    - researched information about a variety of mechanical and chemical processes
    - an evaluation of these processes from technological, economic, and ecological perspectives
    - reference to redox chemistry

You will do best answering these questions if you refer to current scientific advances in your answer, as you address the technological and societal aspects of the question. Try to stay up-to-date on current events by reading the newspaper, science magazines, or reliable science Web sites on a regular basis. Make sure that your answer includes both scientific and technology and society aspects.

Write your answer out in full. When you have completed your answer, **recheck** it against the bullets, making sure all parts of the question have been addressed.

The open response questions are scored against **two** separate scales: a **science** scale, and a **technology and society** scale. The scores are: 0 (insufficient), 1 (poor), 2 (limited), 3 (satisfactory), 4 (good) and 5 (excellent). The highest score (5) is given for clear, complete answers that address all of the directing words and give more than one example or piece of information for each bullet in the question. The lowest response (0) is given if the answer does not address the questions presented, or is too brief to assess.

Appendix I DATA TABLES

THERMODYNAMIC PROPERTIES OF SELECTED ELEMENTS*

Name	Formula	$\Delta_{fus}H_m^0$ (kJ/mol)	$\Delta_{vap}H_m^0$ (kJ/mol)	c (J/(g·°C))
aluminium	Al	10.79	294	0.897
argon	Ar	1.18	6.43	0.520
beryllium	Be	7.90	297	1.825
boron	B	50.2	480	1.026
bromine	Br_2	10.57	29.96	0.474
carbon (graphite)	C	117	–	0.709
chlorine	Cl_2	6.40	20.41	0.479
chromium	Cr	21.0	339.5	0.449
cobalt	Co	16.06	377	0.421
copper	Cu	12.93	300.4	0.385
fluorine	F_2	0.51	6.62	0.824
gallium	Ga	5.58	254	0.371
germanium	Ge	36.94	334	0.320
gold	Au	12.72	324	0.129
helium	He	0.014	0.08	5.193
hydrogen	H_2	0.12	0.90	14.304
iodine	I_2	15.52	41.57	0.214
iron	Fe	13.81	340	0.449
krypton	Kr	1.64	9.08	0.248
lead	Pb	4.78	179.5	0.129
magnesium	Mg	8.48	128	1.023
manganese	Mn	12.91	221	0.479
mercury	Hg	2.29	59.1	0.140
neon	Ne	0.33	1.71	1.030
nickel	Ni	17.04	377.5	0.444
nitrogen	N_2	0.71	5.57	1.040
oxygen	O_2	0.44	6.82	0.918
phosphorus	P_4	0.66	12.4	0.769
platinum	Pt	22.17	469	0.133
radon	Rn	3.25	18.10	0.094
scandium	Sc	14.1	332.7	0.568
selenium	Se	6.69	95.48	0.321
silicon	Si	50.21	359	0.705
silver	Ag	11.28	258	0.235
sulfur	S_8	1.72	45	0.710
tin	Sn	7.17	296.1	0.228
titanium	Ti	14.15	425	0.523
tungsten	W	52.31	806.7	0.132
uranium	U	9.14	417.1	0.116
vanadium	V	21.5	459	0.489
xenon	Xe	2.27	12.57	0.158
zinc	Zn	7.07	123.6	0.388

* molar enthalpies at 101.325 kPa (1 atm) and specific heat capacities for standard state at SATP

THERMODYNAMIC PROPERTIES OF SELECTED COMPOUNDS*

Name	Formula	$\Delta_{fus}H_m^0$ (kJ/mol)	$\Delta_{vap}H_m^0$ (kJ/mol)	c (J/(g·°C))
ice	$H_2O(s)$	6.01	–	2.00
water	$H_2O(l)$	–	40.65	4.19
steam	$H_2O(g)$	–	–	2.02
ammonia	$NH_3(g)$	5.66	23.33	2.06
methanol	$CH_3OH(l)$	3.22	35.21	2.53
ethanol	$C_2H_5OH(l)$	4.93	38.56	2.44
Freon-12	$CCl_2F_2(g)$	4.14	20.1	0.60

*at 101.325 kPa (1 atm)

MISCELLANEOUS SPECIFIC AND VOLUMETRIC HEAT CAPACITIES

Substance	Specific heat capacity, c (J/(g·°C))	Volumetric heat capacity, c (MJ/(m^3·°C))
air	1.01	0.0012
water	4.19	4.19
wood	1.26	–
glass	0.84	–
polystyrene	0.30	–
brick/rock	–	1.9
concrete	–	2.1
ethylene glycol (50%)	–	3.7
aluminium	0.897	–
copper	0.385	–
tin	0.228	–

STANDARD MOLAR ENTHALPIES OF FORMATION

Chemical name	Formula	$\Delta_f H_m°$ (kJ/mol)
acetone	$(CH_3)_2CO(l)$	−248.1
aluminium oxide	$Al_2O_3(s)$	−1675.7
ammonia	$NH_3(g)$	−45.9
ammonium chloride	$NH_4Cl(s)$	−314.4
ammonium nitrate	$NH_4NO_3(s)$	−365.6
barium carbonate	$BaCO_3(s)$	−1213.0
barium chloride	$BaCl_2(s)$	−855.0
barium hydroxide	$Ba(OH)_2(s)$	−944.7
barium oxide	$BaO(s)$	−548.0
barium sulfate	$BaSO_4(s)$	−1473.2
benzene	$C_6H_6(l)$	+49.1
bromine (vapour)	$Br_2(g)$	+30.9
butane	$C_4H_{10}(g)$	−125.7
calcium carbonate	$CaCO_3(s)$	−1207.6
calcium chloride	$CaCl_2(s)$	−795.4
calcium hydroxide	$Ca(OH)_2(s)$	−985.2
calcium oxide	$CaO(s)$	−634.9
calcium sulfate	$CaSO_4(s)$	−1434.5
carbon dioxide	$CO_2(g)$	−393.5
carbon disulfide	$CS_2(l)$	+89.0
carbon monoxide	$CO(g)$	−110.5
chloroethene	$C_2H_3Cl(g)$	+37.3
chromium(III) oxide	$Cr_2O_3(s)$	−1139.7
copper(I) oxide	$Cu_2O(s)$	−168.6
copper(II) oxide	$CuO(s)$	−157.3
copper(I) sulfide	$Cu_2S(s)$	−79.5
copper(II) sulfide	$CuS(s)$	−53.1
1,2-dichloroethane	$C_2H_4Cl_2(l)$	−126.9
dinitrogen tetraoxide	$N_2O_4(g)$	+11.1
ethane	$C_2H_6(g)$	−84.0
ethane-1,2-diol	$C_2H_4(OH)_2(l)$	−454.8
ethanoic (acetic) acid	$CH_3COOH(l)$	−484.3
ethanol	$C_2H_5OH(l)$	−277.6
ethene (ethylene)	$C_2H_4(g)$	+52.4
ethyne (acetylene)	$C_2H_2(g)$	+227.4
glucose	$C_6H_{12}O_6(s)$	−1273.3
hexane	$C_6H_{14}(l)$	−198.7
hydrogen bromide	$HBr(g)$	−36.3
hydrogen chloride	$HCl(g)$	−92.3
hydrogen fluoride	$HF(g)$	−273.3
hydrogen iodide	$HI(g)$	+26.5
hydrogen perchlorate	$HClO_4(l)$	−40.6
hydrogen peroxide	$H_2O_2(l)$	−187.8
hydrogen sulfide	$H_2S(g)$	−20.6
iodine (vapour)	$I_2(g)$	+62.4
iron(II) oxide	$FeO(s)$	−272.0
iron(III) oxide	$Fe_2O_3(s)$	−824.2
iron(II, III) oxide	$Fe_3O_4(s)$	−1118.4
lead(II) bromide	$PbBr_2(s)$	−278.7
lead(II) chloride	$PbCl_2(s)$	−359.4
lead(II) oxide	$PbO(s)$	−219.0
lead(IV) oxide	$PbO_2(s)$	−277.4
magnesium carbonate	$MgCO_3(s)$	−1095.8
magnesium chloride	$MgCl_2(s)$	−641.3
magnesium hydroxide	$Mg(OH)_2(s)$	−924.5
magnesium oxide	$MgO(s)$	−601.6
magnesium sulfate	$MgSO_4(s)$	-1284.9
manganese(II) oxide	$MnO(s)$	−385.2
manganese(IV) oxide	$MnO_2(s)$	−520.0
mercury(II) oxide (red)	$HgO(s)$	−90.8
mercury(II) sulfide (red)	$HgS(s)$	−58.2
methanal (formaldehyde)	$CH_2O(g)$	−108.6
methane	$CH_4(g)$	−74.6
methanoic (formic) acid	$HCOOH(l)$	−425.0
methanol	$CH_3OH(l)$	−239.2
methylpropane	$C_4H_{10}(g)$	−134.2
nickel(II) oxide	$NiO(s)$	−240.6
nitric acid	$HNO_3(l)$	−174.1
nitrogen dioxide	$NO_2(g)$	+33.2
nitrogen monoxide	$NO(g)$	+91.3
nitromethane	$CH_3NO_2(l)$	−113.1
octane	$C_8H_{18}(l)$	−250.1
ozone	$O_3(g)$	+142.7
pentane	$C_5H_{12}(l)$	−173.5
phenylethene (styrene)	$C_6H_5CHCH_2(l)$	+103.8
phosphorus pentachloride	$PCl_5(s)$	−443.5
phosphorus trichloride (liquid)	$PCl_3(l)$	−319.7
phosphorus trichloride (vapour)	$PCl_3(g)$	−287.0
potassium bromide	$KBr(s)$	−393.8
potassium chlorate	$KClO_3(s)$	−397.7
potassium chloride	$KCl(s)$	−436.5
potassium hydroxide	$KOH(s)$	−424.6
propane	$C_3H_8(g)$	−103.8
silicon dioxide (α–quartz)	$SiO_2(s)$	−910.7
silver bromide	$AgBr(s)$	−100.4
silver chloride	$AgCl(s)$	−127.0
silver iodide	$AgI(s)$	−61.8
sodium bromide	$NaBr(s)$	−361.1
sodium chloride	$NaCl(s)$	−411.2
sodium hydroxide	$NaOH(s)$	−425.6
sodium iodide	$NaI(s)$	−287.8
sucrose	$C_{12}H_{22}O_{11}(s)$	−2226.1
sulfur dioxide	$SO_2(g)$	−296.8
sulfur trioxide (liquid)	$SO_3(l)$	−441.0
sulfur trioxide (vapour)	$SO_3(g)$	−395.7
sulfuric acid	$H_2SO_4(l)$	−814.0
tin(II) chloride	$SnCl_2(s)$	-325.1
tin(IV) chloride	$SnCl_4(l)$	-511.3
tin(II) oxide	$SnO(s)$	−280.7
tin(IV) oxide	$SnO_2(s)$	−577.6
2,2,4-trimethylpentane	$C_8H_{18}(l)$	−259.2
urea	$CO(NH_2)_2(s)$	−333.5
water (liquid)	$H_2O(l)$	−285.8
water (vapour)	$H_2O(g)$	−241.8
zinc oxide	$ZnO(s)$	−350.5
zinc sulfide	$ZnS(s)$	−206.0

- Standard molar enthalpies (heats) of formation are measured at SATP (25 °C and 100 kPa). The values were obtained from *The CRC Handbook of Chemistry and Physics*.
- The standard molar enthalpies of elements in their standard states are defined as zero.

RELATIVE STRENGTHS OF OXIDIZING AND REDUCING AGENTS

SOA
Strongest Oxidizing Agents

DECREASING STRENGTH OF OXIDIZING AGENTS

Oxidizing agents		Reducing agents	E°_r (V)
$F_2(g) + 2\,e^-$	$\rightleftharpoons$	$2\,F^-(aq)$	+2.87
$PbO_2(s) + SO_4^{2-}(aq) + 4\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$PbSO_4(s) + 2\,H_2O(l)$	+1.69
$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 4\,H_2O(l)$	+1.51
$Au^{3+}(aq) + 3\,e^-$	$\rightleftharpoons$	$Au(s)$	+1.50
$ClO_4^-(aq) + 8\,H^+(aq) + 8\,e^-$	$\rightleftharpoons$	$Cl^-(aq) + 4\,H_2O(l)$	+1.39
$Cl_2(g) + 2\,e^-$	$\rightleftharpoons$	$2\,Cl^-(aq)$	+1.36
$2\,HNO_2(aq) + 4\,H^+(aq) + 4\,e^-$	$\rightleftharpoons$	$N_2O(g) + 3\,H_2O(l)$	+1.30
$Cr_2O_7^{2-}(aq) + 14\,H^+(aq) + 6\,e^-$	$\rightleftharpoons$	$2\,Cr^{3+}(aq) + 7\,H_2O(l)$	+1.23
$O_2(g) + 4\,H^+(aq) + 4\,e^-$	$\rightleftharpoons$	$2\,H_2O(l)$	+1.23
$MnO_2(s) + 4\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 2\,H_2O(l)$	+1.22
$2\,IO_3^-(aq) + 12\,H^+(aq) + 10\,e^-$	$\rightleftharpoons$	$I_2(s) + 6\,H_2O(l)$	+1.20
$Br_2(l) + 2\,e^-$	$\rightleftharpoons$	$2\,Br^-(aq)$	+1.07
$Hg^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Hg(l)$	+0.85
$ClO^-(aq) + H_2O(l) + 2\,e^-$	$\rightleftharpoons$	$Cl^-(aq) + 2\,OH^-(aq)$	+0.84
$Ag^+(aq) + e^-$	$\rightleftharpoons$	$Ag(s)$	+0.80
$2\,NO_3^-(aq) + 4\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$N_2O_4(g) + 2\,H_2O(l)$	+0.80
$Fe^{3+}(aq) + e^-$	$\rightleftharpoons$	$Fe^{2+}(aq)$	+0.77
$O_2(g) + 2\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$H_2O_2(l)$	+0.70
$MnO_4^-(aq) + 2\,H_2O(l) + 3\,e^-$	$\rightleftharpoons$	$MnO_2(s) + 4\,OH^-(aq)$	+0.60
$I_2(s) + 2\,e^-$	$\rightleftharpoons$	$2\,I^-(aq)$	+0.54
$Cu^+(aq) + e^-$	$\rightleftharpoons$	$Cu(s)$	+0.52
$O_2(g) + 2\,H_2O(l) + 4\,e^-$	$\rightleftharpoons$	$4\,OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Cu(s)$	+0.34
$SO_4^{2-}(aq) + 4\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$H_2SO_3(aq) + H_2O(l)$	+0.17
$Sn^{4+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Sn^{2+}(aq)$	+0.15
$Cu^{2+}(aq) + e^-$	$\rightleftharpoons$	$Cu^+(aq)$	+0.15
$S(s) + 2\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$H_2S(aq)$	+0.14
$AgBr(s) + e^-$	$\rightleftharpoons$	$Ag(s) + Br^-(aq)$	+0.07
$2\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$H_2(g)$	0.00
$Pb^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Pb(s)$	−0.13
$Sn^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Sn(s)$	−0.14
$AgI(s) + e^-$	$\rightleftharpoons$	$Ag(s) + I^-(aq)$	−0.15
$Ni^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Ni(s)$	−0.26
$Co^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Co(s)$	−0.28
$H_3PO_4(aq) + 2\,H^+(l) + 2\,e^-$	$\rightleftharpoons$	$H_3PO_3(aq) + H_2O(l)$	−0.28
$PbSO_4(s) + 2\,e^-$	$\rightleftharpoons$	$Pb(s) + SO_4^{2-}(aq)$	−0.36
$Se(s) + 2\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$H_2Se(aq)$	−0.40
$Cd^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Cd(s)$	−0.40
$Cr^{3+}(aq) + e^-$	$\rightleftharpoons$	$Cr^{2+}(aq)$	−0.41
$Fe^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Fe(s)$	−0.45
$NO_2^-(aq) + H_2O(l) + e^-$	$\rightleftharpoons$	$NO(g) + 2\,OH^-(aq)$	-0.46
$Ag_2S(s) + 2\,e^-$	$\rightleftharpoons$	$2\,Ag(s) + S^{2-}(aq)$	−0.69
$Zn^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Zn(s)$	−0.76
$Te(s) + 2\,H^+(aq) + 2\,e^-$	$\rightleftharpoons$	$H_2Te(aq)$	−0.79
$2\,H_2O(l) + 2\,e^-$	$\rightleftharpoons$	$H_2(g) + 2\,OH^-(aq)$	−0.83
$Cr^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Cr(s)$	−0.91
$Se(s) + 2\,e^-$	$\rightleftharpoons$	$Se^{2-}(aq)$	−0.92
$SO_4^{2-}(aq) + H_2O(l) + 2\,e^-$	$\rightleftharpoons$	$SO_3^{2-}(aq) + 2\,OH^-(aq)$	−0.93
$Al^{3+}(aq) + 3\,e^-$	$\rightleftharpoons$	$Al(s)$	−1.66
$Mg^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Mg(s)$	−2.37
$Na^+(aq) + e^-$	$\rightleftharpoons$	$Na(s)$	−2.71
$Ca^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Ca(s)$	−2.87
$Ba^{2+}(aq) + 2\,e^-$	$\rightleftharpoons$	$Ba(s)$	−2.91
$K^+(aq) + e^-$	$\rightleftharpoons$	$K(s)$	−2.93
$Li^+(aq) + e^-$	$\rightleftharpoons$	$Li(s)$	−3.04

DECREASING STRENGTH OF REDUCING AGENTS

SRA
Strongest Reducing Agents

- 1.0 mol/L solutions at 25 °C and 1 atm
- Values in this table are taken from *The CRC Handbook of Chemistry and Physics*.

RELATIVE STRENGTHS OF AQUEOUS ACIDS AND BASES

	Equilibrium constant, K_a	Acid		Conjugate base	
		Name	Formula	Formula	Name
SA Strongest Acid	very large	perchloric acid	$HClO_4(aq)$	$ClO_4^-(aq)$	perchlorate ion
	very large	hydroiodic acid	$HI(aq)$	$I^-(aq)$	iodide ion
	very large	hydrobromic acid	$HBr(aq)$	$Br^-(aq)$	bromide ion
	very large	hydrochloric acid	$HCl(aq)$	$Cl^-(aq)$	chloride ion
	very large	sulfuric acid	$H_2SO_4(aq)$	$HSO_4^-(aq)$	hydrogen sulfate ion
	very large	nitric acid	$HNO_3(aq)$	$NO_3^-(aq)$	nitrate ion
	1.0	hydronium ion	$H_3O^+(aq)$	$H_2O(l)$	water
	5.4×10^{-2}	oxalic acid	$HOOCCOOH(aq)$	$HOOCCOO^-(aq)$	hydrogen oxalate ion
	1.4×10^{-2}	sulfurous acid ($SO_2 + H_2O$)	$H_2SO_3(aq)$	$HSO_3^-(aq)$	hydrogen sulfite ion
	1.0×10^{-2}	hydrogen sulfate ion	$HSO_4^-(aq)$	$SO_4^{2-}(aq)$	sulfate ion
	6.9×10^{-3}	phosphoric acid	$H_3PO_4(aq)$	$H_2PO_4^-(aq)$	dihydrogen phosphate ion
	5.6×10^{-3}	nitrous acid	$HNO_2(aq)$	$NO_2^-(aq)$	nitrite ion
	7.4×10^{-4}	citric acid*	$H_3C_6H_5O_7(aq)$	$H_2C_6H_5O_7^-(aq)$	dihydrogen citrate ion*
	6.3×10^{-4}	hydrofluoric acid	$HF(aq)$	$F^-(aq)$	fluoride ion
	1.8×10^{-4}	methanoic acid	$HCOOH(aq)$	$HCOO^-(aq)$	methanoate ion
	1.5×10^{-4}	hydrogen oxalate ion	$HOOCCOO^-(aq)$	$OOCCOO^{2-}(aq)$	oxalate ion
	9.1×10^{-5}	ascorbic acid	$H_2C_6H_6O_6(aq)$	$HC_6H_6O_6^-(aq)$	hydrogen ascorbate ion
	6.3×10^{-5}	benzoic acid	$C_6H_5COOH(aq)$	$C_6H_5COO^-(aq)$	benzoate ion
	1.8×10^{-5}	ethanoic (acetic) acid	$CH_3COOH(aq)$	$CH_3COO^-(aq)$	ethanoate (acetate) ion
	1.7×10^{-5}	dihydrogen citrate ion*	$H_2C_6H_5O_7^-$	$HC_6H_5O_7^{2-}$	hydrogen citrate ion*
	4.5×10^{-7}	carbonic acid ($CO_2 + H_2O$)	$H_2CO_3(aq)$	$HCO_3^-(aq)$	hydrogen carbonate ion
	4.0×10^{-7}	hydrogen citrate ion*	$HC_6H_5O_7^{2-}$	$C_6H_5O_7^{3-}$	citrate ion*
	8.9×10^{-8}	hydrosulfuric acid	$H_2S(aq)$	$HS^-(aq)$	hydrogen sulfide ion
	6.3×10^{-8}	hydrogen sulfite ion	$HSO_3^-(aq)$	$SO_3^{2-}(aq)$	sulfite ion
	6.2×10^{-8}	dihydrogen phosphate ion	$H_2PO_4^-(aq)$	$HPO_4^{2-}(aq)$	hydrogen phosphate ion
	4.0×10^{-8}	hypochlorous acid	$HClO(aq)$	$ClO^-(aq)$	hypochlorite ion
	6.2×10^{-10}	hydrocyanic acid	$HCN(aq)$	$CN^-(aq)$	cyanide ion
	5.8×10^{-10}	boric acid	$H_3BO_3(aq)$	$H_2BO_3^-(aq)$	dihydrogen borate ion
	5.6×10^{-10}	ammonium ion	$NH_4^+(aq)$	$NH_3(aq)$	ammonia
	1.0×10^{-10}	phenol	$C_6H_5OH(aq)$	$C_6H_5O^-(aq)$	phenoxide ion
	4.7×10^{-11}	hydrogen carbonate ion	$HCO_3^-(aq)$	$CO_3^{2-}(aq)$	carbonate ion
	2.2×10^{-12}	hydrogen peroxide	$H_2O_2(aq)$	$HO_2^-(aq)$	hydrogen peroxide ion
	2.0×10^{-12}	hydrogen ascorbate ion	$HC_6H_6O_6^-(aq)$	$C_6H_6O_6^{2-}(aq)$	ascorbate ion
	4.8×10^{-13}	hydrogen phosphate ion	$HPO_4^{2-}(aq)$	$PO_4^{3-}(aq)$	phosphate ion
	1.3×10^{-13}	hydrogen sulfide ion	$HS^-(aq)$	$S^{2-}(aq)$	sulfide ion
	1.0×10^{-14}	water (55.5 mol/L)	$H_2O(l)$	$OH^-(aq)$	hydroxide ion
	very small	hydroxide ion	$OH^-(aq)$	$O^{2-}(aq)$	oxide ion

DECREASING STRENGTH OF ACIDS

DECREASING STRENGTH OF BASES

SB Strongest Base

* The molecular formula representing (triprotic) citric acid has been compressed here to its simplest form for ease of use when writing proton transfer equations.

Values in this table are taken from *Lange's Handbook of Chemistry* for 25 °C.

Appendix J COMMON CHEMICALS

You live in a chemical world. As one bumper sticker asks, "What in the world isn't chemistry?" Every natural and technologically produced substance around you is composed of chemicals. Many of these chemicals are used to make your life easier or safer, and some of them have life-saving properties. Following is a list of selected common chemicals. The chemicals marked with an asterisk are to be memorized.

Common name	Recommended name	Formula	Common use/source
acetic acid*	ethanoic acid	$CH_3COOH(aq)$	vinegar
acetone*	propanone	$(CH_3)_2CO(l)$	nail polish remover
acetylene*	ethyne	$C_2H_2(g)$	cutting/welding torch
ASA (Aspirin®)	acetylsalicylic acid	$C_6H_4COOCH_3COOH(s)$	for pain relief medication
baking soda*	sodium hydrogen carbonate	$NaHCO_3(s)$	leavening agent
battery acid*	sulfuric acid	$H_2SO_4(aq)$	car batteries
bleach	sodium hypochlorite	$NaClO(s)$	bleach for clothing
bluestone	copper(II) sulfate—(1/5)-water	$CuSO_4 \cdot 5\,H_2O(s)$	algicide/fungicide
brine*	aqueous sodium chloride	$NaCl(aq)$	water-softening agent
citric acid	2-hydroxy-1,2,3-propanetricarboxylic acid	$C_3H_4OH(COOH)_3$	in fruit and beverages
CFC	chlorofluorocarbon	$C_xCl_yF_z(l)$; e.g.,$C_2Cl_2F_4(l)$	refrigerant
charcoal/graphite*	carbon	$C(s)$	fuel/lead pencils
dry ice*	carbon dioxide	$CO_2(g)$	"fizz" in carbonated beverages
ethylene*	ethene	$C_2H_4(g)$	for polymerization
ethylene glycol*	ethane-1,2-diol	$C_2H_4(OH)_2(l)$	radiator antifreeze
freon-12	dichlorodifluoromethane	$CCl_2F_2(l)$	refrigerant
Glauber's salt	sodium sulfate—(1/10)-water	$Na_2SO_4 \cdot 10\,H_2O(s)$	solar heat storage
glucose*	D-glucose; dextrose	$C_6H_{12}O_6(s)$	in plants and blood
grain alcohol*	ethanol (ethyl alcohol)	$C_2H_5OH(l)$	beverage alcohol
gypsum	calcium sulfate—water	$CaSO_4 \cdot 2\,H_2O(s)$	wallboard
lime (quicklime)*	calcium oxide	$CaO(s)$	masonry
limestone*	calcium carbonate	$CaCO_3(s)$	chalk and building materials
lye (caustic soda)*	sodium hydroxide	$NaOH(s)$	oven/drain cleaner
malachite	copper(II) hydroxide carbonate	$Cu(OH)_2 \cdot CuCO_3(s)$	copper mineral
methyl hydrate*	methanol (methyl alcohol)	$CH_3OH(l)$	gas-line antifreeze
milk of magnesia	magnesium hydroxide	$Mg(OH)_2(s)$	antacid (for indigestion)
MSG	monosodium glutamate	$NaC_5H_8NO_4(s)$	flavour enhancer
muriatic acid*	hydrochloric acid	$HCl(aq)$	in concrete etching
natural gas*	methane	$CH_4(g)$	fuel
PCBs	polychlorinated biphenyls	$(C_6H_xCl_y)_2$; e.g., $(C_6H_4Cl_2)_2(l)$	in transformers
potash*	potassium chloride	$KCl(s)$	fertilizer
road salt*	calcium chloride or sodium chloride	$CaCl_2(s)$ or $NaCl_2(s)$	melts ice
rotten-egg gas*	hydrogen sulfide	$H_2S(g)$	in natural gas
rubbing alcohol	propan-2-ol	$CH_3CHOHCH_3(l)$	for massage
sand (silica)	silicon dioxide	$SiO_2(s)$	in glass making
slaked lime*	calcium hydroxide	$Ca(OH)_2(s)$	limewater
soda ash*	sodium carbonate	$Na_2CO_3(s)$	in laundry detergents
sugar*	sucrose	$C_{12}H_{22}O_{11}(s)$	sweetener
table salt*	sodium chloride	$NaCl(s)$	seasoning
washing soda*	sodium carbonate—(1/10)-water	$Na_2CO_3 \cdot 10\,H_2O(s)$	water softener
vitamin C	ascorbic acid	$H_2C_6H_6O_6(s)$	vitamin